SPECIAL UTILITY
TRAINING MANUAL

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ENVIRONMENTAL MANAGEMENT DIVISION
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PREFACE

This manual was prepared primarily as a study guide for those public utility applicators who are involved in applications of herbicides and wood preservatives on utility right-of-ways. Persons who demonstrate a knowledge of the material contained in this manual plus the Basic Pesticide Training Manual can be licensed in the Special Utility category.

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INTRODUCTION TO WEEDS

Most of the plants that we commonly consider weeds have existed in the world for many years but were not economically important until man started growing plants for food. Weeds are objectionable because they have the ability to compete with plants grown for food, animal feed and fiber. They can also destabilize soils, increase fire hazards and significantly reduce land values.

A weed can be defined in many ways: 1) a plant growing where it is not wanted; 2) a plant out of place; or 3) a plant that is more harmful than beneficial. Any plant can be a weed in a given circumstance. Kentucky bluegrass that spreads into a flower bed is a weed; volunteer wheat in a sugar beet field is a weed. A plant is a weed only in terms of individual definition.

The plants that are commonly referred to as weeds have characteristics that give them the ability to spread and compete with most cultivated plants. Most major weeds have at least several of the following characteristics:

> 1. continuous seed production for as long as growing conditions permit;
>
> 2. unique ways of dispersing and spreading, including vegetative propagation and seed transport mechanisms;
>
> 3. ability of seeds to avoid predation and remain dormant in soil for long periods of time;
>
> 4. ability to grow under adverse conditions;
>
> 5. genetic adaptation to a wide variety of soil and climatic conditions;
>
> 6. compete for soil moisture, nutrients and sunlight.

Economic losses caused by weeds occur every year in Montana. Weeds cause losses to agricultural production by:

> 1. decreasing crop yields by removal of water and nutrients from the soil. Some weeds need more water to produce one pound of dry matter than do most of the cereal grains.
>
> 2. weed seeds in grain reduce the value of these products.
>
> 3. dairy animals that eat certain weeds may produce milk with an unpleasant odor or off-flavor.
>
> 4. weed control requires extra tillage operations in preparing soil for planting.

5. irrigation costs are increased by weeds growing in and along irrigation ditches. This often results in decreased water flow and added weed control costs.

6. weed infestations may serve as a source of plant diseases and insect pests. Weeds may also act as alternate hosts for diseases and insect vectors.

7. some weeds are poisonous to humans and livestock if handled or eaten. To produce crops efficiently, it is necessary to reduce the effect of competition by weeds. Although weeds cannot be entirely eliminated, they can be reduced to manageable levels.

A. <u>SOURCES OF WEED INFESTATION</u>

<u>People</u> are probably the most active agent in the dissemination of weeds. Most exotic plants found in the United States are here because of the movement of man and his products. Weed seeds are moved by people in many ways, including in hay and seed products as well as by machinery and vehicles. Common carriers, railroads and trucks hauling cargoes of grain, hay, livestock, and other farm commodities scatter many seeds along right-of-ways and highways, which in turn become sources of infestation to adjoining fields.

<u>Wind</u> spreads seeds over great distances. Many weed seeds have structural features which aid their distribution by wind. Some seeds have wings, like those of maple trees, or they may have long, silky hairs which act like parachutes. Tumbleweeds are especially adapted for seed dispersal along the ground by wind. Russian thistle, for example, breaks off at the soil line when mature and rolls, scattering seeds as it goes.

<u>Water</u> is another method of seed dispersal. Most weed seeds will float if they fall on the surface of streams, lakes or irrigation canals. Flood waters, running streams, and irrigation water are all important in spreading weed seeds. Irrigation canals, when first filled, often carry heavy loads of weed seeds. The seeds are moved downstream where they may be deposited in silt along the way, or dispersed over crops while irrigating.

<u>Animals</u> also aid in the dispersal of seed. The viability of most weed seeds is unaffected by passage through the digestive tracts of animals. Many weeds, such as cocklebur, sanbur, and begger-ticks have awns or hooks on the seeds that attach to the hair of animals, thus aiding in their dispersal. Many hard coated seeds must pass through animals so that the enzymes can soften the seed cover to allow water absorption.

<u>Machinery</u> operation can also spread weed seeds. Wet soils containing weed seeds stick to vehicles and equipment. Tracked equipment tends to accumulate soil and any seeds contained in the soil. Equipment should be cleaned before moving to a new site.

CHAPTER II

CLASSIFICATION OF WEEDS

Weeds can be classified in several different ways: by plant habitat, life cycle, or plant structure. A discussion of each classification is important because identification and control practices are influenced by these classifications.

A. HABITAT

Plant habitat refers to where the plant grows. Terrestrial plants live on land while aquatic plants are structurally modified to live in and around water. For a more complete discussion of aquatic vegetation refer to the Montana Department of Agriculture's "Aquatic Weed Training Manual".

B. LIFE CYCLE

The life cycle describes how long each plant lives and timing of vegetative and seed development.

Annuals complete their life cycle from seed to maturity in less than one year. Summer annual seeds germinate in the spring, flower and produce seed in mid-to late-summer, and die in the fall. Winter annual seeds germinate from late summer to early spring, flower and produce seed in mid-to late-spring and die in the summer. Classification of winter or summer annuals often depends on geography and climate.

Kochia, lambsquarters, redroot and prostrate pigweed, Russian thistle, green and yellow foxtail, and crabgrass are all examples of summer annuals. Winter annuals include common chickweed, downy brome, and many of the mustards.

Control of annual weeds must be accomplished before the plant produces seed. This is most effective when the plant is in the seedling stage. Weeds are small and succulent and less energy is required to control at this stage. Control during the vegetative stage is possible but more difficult since the plant is putting energy into the production of stems, leaves and roots. Chemical control of annuals during the flowering stage is not feasible because most of the plant's energy is going into seed production. Maturity and seed set completes the annual plant life cycle. Control is not effective at this stage.

Biennials live for two growing seasons. Seeds germinate in the spring, summer, or fall of the first year and plants overwinter as a basal rosette of leaves with a thick storage root. The plants flower and produce seed the growing season of the second year and die. Common biennials include sweetclover, mullein, burdock, wild carrot, bull thistle and musk thistle.

Effective control of biennial plants is very similar to control for annuals. Early spring or fall spraying of the rosette is an effective time for control.

Perennials produce vegetative structures, allowing them to live for more than two years. They reproduce by seed, while many can also spread vegetatively. Most perennials which reproduce entirely by seed overwinter by means of a vegetative structure, such as a

perennial root with a "crown". Creeping perennials both overwinter and produce new, independent plants from vegetative reproductive tissues. These structures include rhizomes, tubers, bulbs, stolons and creeping roots. Creeping perennials can also reproduce from seeds.

Dandelion and curly dock are common examples of simple perennials. Quackgrass, Canada thistle, leafy spurge and field bindweed are creeping perennials.

Perennial weed control must be aimed at either the seedling or the regrowth stages of development. Chemical control during the vegetative growth stages is mediocre. Control during flowering is ineffective but is effective just prior to flowering (bud stage). Control at maturity is not feasible since the above ground portions of the plant die back at this time. Fall treatment of regrowth is most effective because the plant is translocating nutrients to the root system and will also translocate herbicide to kill the roots. To achieve effective control of perennials, underground plant parts must be killed.

C. PLANT STRUCTURE

Differences in plant structure or life form are important to recognize. For weed control purposes plants are divided into three main categories - grasses, broadleaves(forbs) and woody stemmed.

Grass plants have one seed leaf (monocot). They typically have parallel leaf venation, narrow, upright leaves and flower parts in threes or multiples of threes. Examples include quackgrass, green foxtail and downy brome.

Broadleaf plants (forbs) have two seed leaves (dicots). They generally have broad, net-veined leaves and flower parts in four, five or multiples thereof. Examples include kochia, sunflower, and Canada thistle.

Woody stemmed plants persist from year to year with woody aerial stems and include shrubs and trees. Shrubs have several stems and are generally less than ten feet tall. Trees have a single stem and are over ten feet tall. Multiflora rose, sagebrush and snowberry are examples of woody weed plants.

CHAPTER III

METHODS OF CONTROLLING WEEDS

For a weed control program to be successful, weeds or undesirable plants must be destroyed without damaging crops or desirable plants. The most effective or economical method or combination of methods for weed control depends upon the situation. Herbicides are a supplement to good cultural and management practices and are not a replacement for them.

Good farming and land management practices should be first in any weed control program. Causes of weed problems should be identified and corrected by implementation of a integrated management program, including all effective control methods.

Methods that can be used for weed control include: 1) prevention, 2) cultural and mechanical control, 3) biological control, and 4) chemical control.

A. PREVENTION

Prevention is the most practical method of controlling weeds. If weeds are not allowed to occupy an area and produce seed they will not establish. Once weeds are established they are difficult and costly to control. Their seeds may remain dormant in the soil for many years.

Preventive control measures should be adapted where practical and include: a) immediately reseed disturbed areas; b) avoid crossing weed patches; c) after work in weed infested areas remove any weeds or seeds from the equipment; d) throughly clean soil which may contain seeds from equipment before moving to a weed free area.

B. CULTURAL AND MECHANICAL CONTROL

Cultural and mechanical control methods include tillage, hoeing, mowing, mulching, crop competition, and crop rotation.

Mowing can be an effective weed control practice under certain conditions. It should be part of an overall crop management program. Mowing controls weeds by preventing seed production, depleting underground food reserves, and by favoring growth of more competitive plants. Plants must have a relatively tall growth habit to prevent seed production. Mowing must be done prior to seed maturity. Since most plants regenerate, repeated mowing is required for adequate weed control. It is important to remember that repeated mowing may change upright, single stemmed plants into prostrate, multi-stemmed plants that can still set seed.

C. BIOLOGICAL CONTROL

Biological weed control is the use of a living organism to control weeds. Insects are the most commonly used agent but fish, nematodes, snails, fungi and bacteria offer additional means of controlling plants.

Biological controls can be useful for suppression of unwanted plants, generally in a non-crop situation. Development of a biocontrol agent is time-consuming and expensive. Host specific biocontrol agents are generally needed to prevent damage to desirable plants. Usually several different agents are needed to give economic control of a single weed species. Biological control is not recommended in cropland situations because of a lack of adequate economic threshold data for weeds. In a field situation, there are usually several other weed species that will fill in a void left when one plant is taken out by a biological control agent.

D. <u>CHEMICAL CONTROL</u>

Use of herbicides for weed control is common in Montana. Research over the past few decades has produced many new chemicals for use in weed control. Chemicals are now widely used and will continue to play an important role in agriculture.

E. <u>WEED CONTROL VERSUS WEED MANAGEMENT</u>

Specific weed control methods have been outlined in this chapter. All of these tools must be used to effectively manage weed infestations. Annual, biennial, and perennial weeds have certain growth habits that influence the type of control method or methods implemented. Soil type, weather conditions, recreational activity, wildlife or domestic grazing and future use of the land will also influence your choice of weed control tools. Consider all information known about the weed and the site as you develop a long term management plan for control of a weed infestation.

CHAPTER IV

CHEMICAL WEED CONTROL

Herbicides are effective tools when used properly. Since the early 1950's, thousands of chemicals have been evaluated for effectiveness as weed killers. Herbicides are available for controlling many weeds growing in various environments including cropland, rangeland, gardens, lawns, ditchbanks, noncrop areas, and in irrigation, drainage, navigable, and potable waters. Because of the many factors and principles involved in research on herbicides, information about chemical weed control is rapidly increasing. New recommendations are continually replacing old ones. Be sure to read and follow all label directions from a <u>current</u> product label.

A. SELECTIVE HERBICIDES

Chemicals which can be used to remove certain plant species with little or no effect on other species are referred to as selective herbicides. Selectivity depends on the amount of chemical used, the application method, the degree of foliage wetting, soil moisture and texture, temperature, and humidity. Since selectivity can be influenced by all of these factors, the same chemical may be either selective or non-selective, depending on the amount used. For example, atrazine used at a high rate is an effective soil sterilant (non-selective) and used at a lower rate is a selective herbicide for weed control in corn.

     1. Foliage applications are treatments made to the leaves of growing plants, usually as a spray or mist.

     a.   Translocated herbicides move within the plant after the material is absorbed into the tissue. The greatest amount of transport is through the vascular system of the plant (phloem and xylem). Translocated herbicides may be effective in destroying roots as well as top growth of plants. Selectivity depends on physiological differences of plants. A commonly used selective, translocated herbicide used in Montana is 2,4-D.

     b.   Contact herbicides do not translocate or move in the plant. This group of herbicides kills only the plants or portion of the plant actually contacted by the chemical. In order to obtain effective control, adequate coverage of the foliage is essential. This may be accomplished by using a high volume of carrier or diluent to apply the herbicide. Dinitrophenols and certain petroleum oils are used as selective, contact herbicides.

     2. Soil applications are herbicide treatments applied to the soil. To be effective, the chemical must be carried into the soil by moisture or mechanical incorporation. Selectivity depends on the plant tolerance, soil texture, location of the herbicide in the soil, and difference in growth habit of the crop and the weed. These herbicides are generally translocated.

     3. Selectivity can also be determined by timing of applications:

     a.   Preplant treatments are made to the soil before the crop is planted. Typical preplant treatments are applied after seed bed preparation but before planting the crop.

This type of treatment is considered pre-emergence with respect to weeds if applied prior to crop seed germination.

b.   Pre-emergence treatments are made to the soil after the crop is planted but before emergence of the crop or the weeds.

c.   Post-emergence herbicides are applied to the soil after the crop or weeds have germinated and started to grow. Other post-emergence treatments may include:

> 1) Pre-harvest herbicide applied to kill weeds before crop harvest to remove weed growth that could interfere with the harvesting operation.
>
> 2) Post-harvest herbicides applied to kill weeds present after harvest as part of the weed control program for the next season.

B. NON-SELECTIVE HERBICIDES

Herbicides which are toxic to all plants may be used to control a wide variety of vegetation in an area. When no selectivity is intended, these chemicals can be used to control vegetation in noncropped areas such as along fence rows, around electrical power lines and substations, right-of-ways, and storage areas.

1. Foliage applications are applied to the leaves of growing plants as sprays.

a.   Translocated herbicides move from the foliage to the roots, resulting in control of a wide variety of plant species. There are few herbicides that can be classified as translocated, non-selective. Glyphosate is one good example.

b.   Contact sprays kill vegetation at the point of contact. One treatment is usually sufficient to control annual weeds. Perennial plants may require more than one treatment for adequate control. Acrolein and paraquat are examples of non-selective contact herbicides.

2. Soil applications include a wide variety of soil fumigants and soil sterilants that are applied directly to the soil. These are used where it is necessary to prevent all plant growth.

a.   Soil fumigants are non-selective chemicals that are most often used to kill all plant growth as well as other soil organisms before planting a desirable species. They function as a vapor or gas which diffuses through the soil and have a short life in the soil. The treated area may be replanted, usually within a month or less. Methyl bromide is a commonly used soil fumigant.

b.   Soil sterilants are chemicals that kill all green plants for a period of several months to several years. They are classified as:

> 1) Temporary sterilants which kill plant life for four months or less.
>
> 2) Semi-permanent sterilants which kill all plant life for four months to two years.

3) Permanent sterilants persist in the soil for longer than two years.

The length of time the herbicide residue remains depends on the herbicide used, the rate of application, microbial activity and the soil moisture, temperature and texture.

C. BASICS OF HERBICIDE SELECTIVITY

It is important to understand how herbicides kill plants, why a herbicide is phytotoxic to one species and not another, and how herbicides can be used to best accomplish the results desired. Selectivity is relative. We want herbicides to selectively control weeds, but not harm the crop.

The most important factors that affect herbicide selectivity are: 1) structural differences in plants, 2) differences in absorption, 3) differences in translocation, 4) physiological differences, and 5) herbicide concentration. Combinations of these factors can be used to improve herbicide selectivity.

1. Structural differences among plants permit selective applications. The narrow, upright leaves of a cereal plant lack the exposed leaf surfaces of a broadleaf plant. Water droplets can stick only to a small portion of an upright leaf surface. On the other hand, a broadleaf plant has a wide leaf surface which extends parallel to the ground and will hold more spray and therefore be affected more by the herbicide. Another important structural difference is the location of the growing point of the plant. The growing point of many grasses is protected because it is located at the base of the plant. Contact sprays may injure the leaves of the grass plant but not contact the growing point. Broadleaf plants have exposed growing points at the tips of the shoots and in the leaf axils. The growing point is therefore more accessible to the herbicide.

Waxiness, hairiness, or pubescence of a plant may prevent spray droplets from adhering to the leaf. If the chemical droplet adheres to the leaf hairs without contacting the leaf surface, it will not be absorbed. On the other hand, hairs may collect and hold droplets, preventing the spray from running off the leaf surface. Waxy leaves may require use of an additive with the herbicide to dissolve the waxy layer and allow contact with the leaf surface.

2. Absorption is the movement of a material into the plant from an external source. Some plant surfaces absorb herbicides quickly; other surfaces may absorb the chemical slowly, if at all. Characteristics of the plant leaf surface, cuticle and stomate, account for differences in absorption.

a. The cuticle is a waxy layer on the leaf surface which retards the movement of water and gases (oxygen and carbon dioxide) into and out of the leaf. The cuticle varies in thickness in different plants and can vary within the same plant species exposed to different environmental conditions. Shaded plants often have thinner cuticles than plants grown in the sun, and young leaves usually have thinner cuticles than older leaves. A herbicide must penetrate the cuticle layer and cell wall. High temperature and low humidity conditions usually results in poor cuticle penetration.

b.   A plant leaf is perforated by small openings or pores called stomates, which open into the intercellular spaces within the leaf. The number and distribution of stomates varies from plant to plant. The stomatal opening can be an effective port of entry for a herbicide if they are open at the time of application. This is why some foliar applied sprays are more effective when applied in the early morning or late evening when there is less sunlight and the stomates are more likely to be open. Stomatal penetration cannot occur unless the surface tension of the spray solution is significantly reduced by the use of wetting agents.

3. After the herbicide is absorbed, it must be translocated within the plant to the site of action. There are two tissue systems in which an herbicide may move in the plants: the phloem, which conducts food from the plant leaf to the stem and roots; and the xylem, which conducts water and nutrients from the roots to the stem and leaves. Herbicides move through these conducting tissues.

a.   Phloem tissues are composed of living cells. It is important, therefore, not to kill the stem and leaf tissues too quickly. Rapid foliage kill will result in poor transport and poor root kill. Movement in phloem will be toward the roots during maturation of the plant and near budding. This indicates the importance of proper timing of an herbicide application, especially for the control of perennial weeds. It is necessary to apply a translocated herbicide when a perennial is storing up root reserves. Most growth regulators, including 2,4-D, as well as amitrole, dalapon, and glyphosate, move readily in phloem tissue.

b.   Xylem tissue of a plant is made up of non-living cells. It is the water conducting, transpiration system in the plant and movement is only from the roots upward to leaf and shoot tips. Any chemicals applied either to the roots or foliage will only be translocated toward the leaf tip. Atrazine, metribuzin, and diuron are examples of xylem conducted herbicides.

4. The physiological differences between plants affect herbicidal toxicity. Differences in enzyme systems, responses to pH changes, cell metabolism, cell permeability, variations in chemical constituents and polarities may all influence the action of a herbicide within the plant. Herbicides that stimulate or block certain biochemical processes in a plant can affect the plant's growth. Enzyme reactions may be blocked in one plant species, but not in another, by the same chemical. Activation of chemical into an active compound, such as 2,4-DB converted to 2,4-D by certain plants, is an example. Decomposition of an herbicide to a harmless compound is another example; corn has enzymes that decompose triazine herbicides into harmless compounds.

5. The rate of application or concentration may determine whether a herbicide inhibits or stimulates plant growth. Under low concentrations, 2,4-D can act as a growth hormone and increase the rate of respiration and cell division, resulting in stimulated plant growth. At higher rates, growth can be abnormal and result in death of the plant. The concentration of an herbicide at certain sites in the plant may determine the herbicide effectiveness.

D. HERBICIDE FORMULATIONS

Almost all herbicides must be combined with a liquid or solid carrier to uniformly distribute them during application. The formulation of a chemical is the manner in which the active ingredient and the carrier are mixed. Proper formulation of agricultural chemicals increases their effectiveness. Inert ingredients make the herbicide easier to handle, less likely to settle out or decompose during storage, and may minimize the hazard while handling the chemical. The way the herbicide is formulated may change its chemical characteristics, including solubility, volatility, and toxicity to plants.

Common types of formulations are classified as follows:

1. Liquid Formulations

a.   Emulsifiable concentrates (EC) are nonpolar (oily) liquids containing emulsifiers, a substance promoting the suspension of one liquid in another. The active ingredient is not soluble in water, but is dispersed in water to form emulsions (droplets of oil surrounded by water). Agitation is usually required to prevent separation.

b.   Water dispersible liquids and granules are often referred to as flowables (F) or dry flowable (DF). These formulations readily disperse in the herbicide carrier. They require a moderate amount of agitation. Both liquids and granules can be added to water without first making a slurry. Water dispersible granules pour cleanly from the container, giving them handling advantages over dispersible liquids and wettable powders.

2. Dry Formulations

a.   Granule formulations have been impregnated into coarsely ground carriers such as clay or vermiculite and formed into small pellets, generally less than 10mm in size. These chemicals are used directly from the bag but require special application equipment, and usually require soil incorporation to be effective.

b.   Solution(s) are herbicides (liquid or powder) that are readily soluble in the carrier liquid. These require no agitation once dissolved in solution. Often they need a surfactant for maximum activity.

c.   A suspension consists of a finely ground wettable powder (WP) dispersed in a liquid. Wettable powders are used if a solid concentrate is preferable to a liquid or if the solubility of a herbicide is so limited that it is impossible to formulate an economical solution or emulsifiable concentrate. These herbicides are nearly insoluble in water or oil but maybe dispersed in them by forming a slurry, adding it to the carrier and using constant agitation.

d.   Pellets are discrete particles usually larger than 10 mm. They are frequently used for spot treatments.

e.   Dusts are finely ground chemicals that may or may not be mixed with diluents. Their use is limited because of the hazard of drift and the high cost of the herbicide.

E. SPRAY ADDITIVES

Adjuvants or spray additives are often used to enhance herbicidal performance or handling. They include surfactants, anti-foaming agents, compatibility agents, crop oils, crop oil concentrates, and drift control agents.

1. Surfactants (surface-active agents) bind two or more incompatible phases, such as water and oil, in more intimate contact by modifying forces between them. A surfactant is any material that affects the surface properties of spray solutions and includes wetting agents, emulsifiers, dispersing agents, detergents, and stickers.

a.   Wetting agents are materials used to increase a liquid's ability to moisten a solid. They lower the surface tension, bringing the liquid into closer contact with the solid. Wetting agents increase or decrease the effectiveness of herbicide sprays; they may also reduce selectivity, especially if selectivity depends on selective wetting or selective absorption.

b.   An emulsifier is a material used to disperse one liquid in another. An emulsion is one liquid dispersed in another, each maintaining its original identity.

c.   Dispersing agents reduce cohesion between particles. They are materials used to disperse the particles of a solid in a liquid. Some dispersing agents also act as wetting agents, but others have little or no effect on surface tension. Some wetting agents and dispersing agents are not compatible and interfere with each other if used together.

d.   Detergents are used to remove dirt or grime. They are usually wetting agents and surface active. Many common detergents have been used with herbicides as wetting agents and emulsifiers. Antifoaming agents can be used to reduce foaming in a sprayer system so pumps and nozzles can operate properly.

e.   A sticker is designed to hold the active ingredient on the sprayed surface.

f.   A penetration agent is any substance that assists plant absorption of an herbicide. Such substances may dissolve the waxy cuticle or fatty portion of the cell wall or membrane of the plant to enhance penetration.

g.   Anticaking agents are used to prevent solid herbicide formulations from forming aggregates.

Surfactants are classified as ionic and nonionic, depending on their disassociation in water. Nonionic agents have no particle charge, while ionic agents have either a positive or negative charge.

Nonionic surfactants are classed as nonelectrolytes and are usually chemically inactive in the presence of usual salts. They can be mixed with most herbicides and still remain chemically inactive. Ionic surfactants ionize in an aqueous medium. These agents can be used to unite oil or water soluble properties of a molecule and allow alignment in water to reduce water surface tension.

2. Compatibility agents aid suspension of herbicides when they are combined in tank mixes with other pesticides, herbicides or fertilizers. They are used frequently when a liquid fertilizer is the carrier solution.

3. Crop oil and crop oil concentrates are non-phytotoxic light oils that also contain surfactants to allow mixing with water. They are added to water solutions to enhance herbicide foliar activity.

4. Drift control agents reduce the fine particles in a spray pattern that are primarily responsible for herbicide drift and nontarget injury.

All adjuvants should be used in accordance with label directions and chosen only from those compatible and proven effective for herbicide applications. Refer to the manufacturer's recommendations and herbicide label recommendations.

F. HERBICIDE APPLICATION

Proper application techniques provide uniform distribution of the herbicide on plant foliage or in the soil. Chemical formulation will usually dictate what type of equipment should be used for application.

1. Spraying is the most common method of application. A spray may be defined as liquid discharged so that it subdivides into particles that scatter and fall as dispersed droplets. Spraying permits reasonably uniform application coverage and allows accurate direction of the herbicide to a given area (such as foliage or soil). Sprays may be applied from sprinkler cans, hand pumps, and compressed air or power sprayers. Most available herbicides can be sprayed using a water carrier. Water acidity or alkalinity can chemically alter an herbicide and may inactivate it. If this is a concern, water pH should be tested.

2. Granules are spread manually or with special mechanical spreaders designed specifically for such use. Granules can be broadcast evenly over the entire crop or in bands over crop rows. This equipment is generally refined fertilizer applicators or seeders and may include attachments for soil incorporation. Granular herbicides have the advantage of being premixed, thus eliminating the need to handle water. The major disadvantages include difficulty in uniform herbicide distribution and lack of versatility of equipment. Granulars are often more expensive than herbicides that are sprayed.

3. Fumigants are injected into the soil by both hand and power-operated equipment. The utility of this equipment is obviously limited and the cost of application is generally very high. Fumigants demand caution in handling since they are highly volatile and extremely toxic. Usually airtight covers must be laid down over treated areas to prevent the escape of vapors. Fumigants will give increased control for soil insects, nematodes, and some plant diseases, as well as weeds.

For more complete information on sprayer calibration and spray equipment maintenance, please refer to the Montana Department of Agriculture Basic Pesticide Equipment Manual.

CHAPTER V

ENVIRONMENTAL FACTORS INFLUENCING
HERBICIDE EFFICACY

Rainfall, soil type and condition, temperature, light and crop type all have a direct effect on herbicide efficacy. Understanding these effects aids in proper herbicide selection, improved weed control, and reduced crop injury.

A. RAINFALL

Time of germination of crop and weed seeds, growth rate, and growth stage at spraying time are partially determined by the incidence and amount of rain. Rain a few days before spraying can improve penetration of an herbicide into a plant by increasing the wettability of the leaf. Rain may mechanically damage the wax structure of the leaf surface, making the plant more susceptible to chemical absorption. The wax, cuticle and hair on the leaf surface, the angle of the leaf, and the humidity of the air help to determine how much chemical is retained and absorbed.

Rain, during or closely following application of an herbicide, may wash the spray from the leaves and reduce its effectiveness. The degree of leaf washing depends, not only on the quantity of rain and its intensity, but also on the structure of the crop-weed stand. The leaf penetration of herbicides ceases, or is reduced, a few hours after application when droplets have dried. Traces of rain, dew, or fog after spraying can increase penetration.

The relative humidity at the time of chemical application and for many days after application, will effect the degree of weed kill. Moist air generally increases herbicide penetration, absorption, and translocation within the weed. Crop density and stand height also effects the relative humidity in the area.

B. SOIL

Soil composition and moisture influences herbicide persistence. The length of time that an herbicide remains active or persists in the soil influences the length of time weed control can be expected. It also determines the length of time until a sensitive crop can be grown in a treated area. Persistence is a desirable or undesirable characteristic depending on the crops to be grown or the weeds to be controlled.

> 1. Soil moisture, rainfall or irrigation is essential in a successful weed control program. Sufficient moisture stimulates uniform germination of weed seeds and vigorous growth of the plant. Chemical application under these conditions is more likely to succeed than when the soil is dry prior to treatment.
>
> Dry conditions cause uneven germination of the weeds and delay crop development. As a result, proper timing of post-emergence herbicides is difficult. Weeds will be uneven in size and difficult to kill and the crop may be at a stage where injury could occur.
>
> Water stress can affect herbicide retention, penetration, and absorption. Leaves grown under water stress have a thicker cuticle and a lower wettability than leaves from plants not under stress.

2. Factors having the greatest effect on herbicide soil residues are leaching, fixation on soil particles, solar, chemical and microbial decomposition, and volatilization.

a.   Leaching is the movement of an herbicide through the soil. (The extent to which a chemical is leached depends upon its solubility in water and the bonding relationship between the herbicide and the soil.) In general, water soluble herbicides and those not readily attached to soil particles are most readily leached.

b.   Fixation, or adsorption, of herbicides onto soil particles reduces the amount of herbicide that may be leached into ground water. Soils high in organic matter or clay-type soils tend to hold herbicides for a longer period of time. This may slow the rate of chemical release and either prolong or lessen its effectiveness.

c.   Chemical decomposition, involving reactions such as oxidation, reduction, and hydrolysis,breaks down most herbicides. Very little is known about the effects of soil chemistry on herbicides.

d.   Microorganisms in the soil are responsible for much herbicide decomposition. Algae, fungi, and bacteria need food for energy and growth. Organic compounds in the soil, including herbicides, provide most of this food. Warm, moist, well-aerated, fertile soils are most favorable to soil microbes and, under ideal conditions, will quickly decompose most organic herbicides. The effect of herbicides on the microbe population is minor when used at normal field rates.

e.   Volatilization causes herbicide loss to the atmosphere as a gas. All chemicals have a vapor pressure and this usually increases as the temperature rises. The gases formed may be toxic to plants and may drift to susceptible plants. Water will leach the herbicide into the soil and aid soil adsorption. Once adsorbed, the loss by volatilization is greatly reduced.

C. TEMPERATURE

Soil temperatures influence germination and growth rates of weeds and crops. Air temperatures at the time of spraying are important in determining the plant response to the herbicide. Warm temperature generally increase the activity of herbicides. There is also an increase in translocation at higher temperatures. In general, warm temperatures before and after spraying appear to increase weed susceptibility and mortality, but extremely high temperatures may reduce penetration by causing wilting, closing of leaf openings, and evaporation of the spray drops. Warm temperatures also increase the incidence of herbicide drift or volatilization.

Temperature changes produce metabolic changes in some plants which effect their susceptibility to herbicides. A plant growing under low temperature conditions may not produce a particular metabolic substance which is necessary to activate a herbicide response. Tests indicate this occurs in plants such as big sagebrush or rabbitbrush, which do not respond to 2,4-D at low temperatures and low moisture. Temperature also has an effect on direction of movement in a plant. Work on mesquite shows 2,4,5-T movement is toward the base of the plant at 70 degrees and toward the top at 86 degrees.

Temperatures have important effects on the dissipation of herbicides from plant foliage or from soil. Some esters of 2,4-D evaporate readily. When such herbicides are applied at

high temperatures their loss as vapors is quite rapid. These losses reduce herbicide effectiveness and increase off- site drift.

D. <u>LIGHT</u>

Light is essential for plant growth. Weed growth in a crop situation can be affected by shading. Growth response to shading will vary among species.

The leaf surface may be affected by light intensity. Leaves have less cuticle, cutin, and wax when grown in the shade. This might lead to differences in susceptibility of the leaf wax structure to weathering and abrasion. (Leaf wettability increases under shade conditions.)

Light (visible and ultraviolet light) can cause decomposition of some herbicides also. It is difficult to determine the relative importance of this phenomenon in the field where the herbicide may be lost through other factors, but it can be demonstrated under laboratory conditions. Loss from photodecomposition of such herbicides as the dinitroalinines, when not soil incorporated, can be important in a field situation.

WEEDS AND HERBICIDES IN THE ENVIRONMENT

The main reason for controlling weeds is to change the environment to permit efficient production of food and fiber. All weed control practices alter the environment whether it is hand pulling, hoeing, cultivating, burning, chemical application, or use of biological control agents. Our concern is that the change to the environment does not produce harmful side effects to nontarget plants, soil, water, animals, or man.

A. DRIFT AND VOLATILITY OF HERBICIDES

Herbicides, if used correctly, can be useful tools in land management programs, but if used incorrectly, they can create serious problems. With greater emphasis on a healthy environment, it is important that herbicides be applied in a proper manner. Persons applying pesticides must understand such things as spray drift, spray volatility and chemical leaching to prevent damage to nontarget organisms and sites.

1. Spray drift is the movement of spray particles out of an intended area. Drift is dependent mainly on a) droplet size; b) wind velocity; c) air temperature; and c) height above the ground. A water droplet five microns in diameter dropped from a heighth of 10 feet can drift over three miles when the wind velocity is three mph. Certain atmospheric conditions associated with high temperatures can cause thermal updrafts which can lift spray droplets into the air and deposit them a considerable distance away.

In the last few years, several methods of reducing drift have been attempted. The most advertized method has been invert emulsions. Esters of 2,4-D make a milk-like "oil-in-water" emulsion that sprays like water. If the emulsion is reversed (inverted) to a "water-in-oil" liquid, and with proper spray equipment, the mixture can be sprayed in large droplets. Other methods for reducing drift include using shields, placing more nozzles on the boom, reducing pressures, and use of drift control additives.

2. A considerable body of literature exists on the volatility of esters of 2,4-D and related compounds. Volatilization is the tendency of a sprayed material to vaporize after it has hit the soil or plant surface. Because of the small amount of herbicide material involved, volatility is usually a hazard only when extremely sensitive crops are nearby. For example, cotton is sensitive to as little as 1/1000 pound per acre of 2,4-D. Tomatoes and some ornamentals are also sensitive to 2,4-D damage. Volatility can be controlled only by reducing the tendency of the chemical to vaporize. The major herbicide which causes economic crop damage because of volatility is 2,4-D. The crystals of 2,4-D acid and amines of 2,4-D are less volatile. The ester formulations have varying degrees of volatility depending on the type of alcohol used to make the ester. Butyl, ethyl, and propyl esters of 2,4-D are very volatile and should not be used if sensitive crops are growing in the area. Iso-octyl and propylene-glycol are examples of ester formulations which are classified as low volatile and do not vaporize easily. These esters are about ten to twenty times less volatile. However, all forms of amines are less volatile than any of the ester forms. In the last few years, attempts to reduce volatility have resulted in the formulation of 2,4-D acid in oil mixtures

and more recently in oil soluble amine formulations. To spray an amine with oil will usually increase its effectiveness to equal that of an ester formulation.

B. PROTECTION OF NONTARGET PLANTS

By far the greatest hazard associated with herbicides is the phytotoxic effect on nontarget plants caused by incorrect or inaccurate application.

Spray drift, in either particle or vapor form, deposited on plant foliage; soil contamination resulting on root uptake by nontarget plants; excessive soil persistence causing injury to subsequent crops; or sprayer contamination are examples of hazards that should be avoided. Beause of the effects that herbicides produce on plants, their presence can be readily detected by characteristic symptoms.

Spray drift of certain soil applied or persistent non-crop herbicides can injure susceptible nontarget plants (beans, sugar beets), even when the drift occurs before seeding the crop.

Plant growth regulating (hormone-like) herbicides present the greatest hazard to nontarget broadleaf plants. Conversion to a vapor associated with temperatures of about 90 degrees and higher can be a hazard with low volatile ester forms of 2,4-D and related herbicides. High volatile 2,4-D esters present an extreme vapor hazard and their use should be confined to areas where sensitive crops are not in close proximity.

All of the herbicides listed below are plant growth regulators and can promote abnormal plant growth when found in trace amounts. Once these herbicides are used, adequate decontamination of sprayers poses a problem, especially if the sprayer is multipurpose and must be used for application of other pesticides. Emulsifiable (oil-soluble) forms such as esters and oil soluble amines are more difficult to clean from spray equipment than the water soluble metallic and amine salts.

Herbicides that May Present a Drift or Equipment Contamination Problem

2,4-D	picloram
MCPA	dicamba
MCPB	fenac

There are several suggested decontamination procedures (see MDA, Basic Pesticide Equipment Manual). Using the right procedure and with enough effort, decontamination can be accomplished. When using sprayers for multiple use applications, extreme care should be exercised.

It should be remembered that all herbicides are subject to drift under certain conditions. Good judgment should be used when applying any herbicide.

TOXICITY OF HERBICIDES

Any herbicide, in large enough doses, can pose a serious health hazard. However, at recommended rates, most herbicides are relatively non-toxic to man and the environment. Herbicides, as with all pesticides, should be used only according to label directions. The information provided on the label is for the safety of the applicator as well as for anyone in the area and label directions, including use of safety equipment, should be carefully followed.

A. TOXICITY CLASSIFICATION

All pesticides are classified according to their toxicity. The following table indicates the **relative** toxicity of most herbicides to man and the approximate dose necessary to cause death. To find the common names of herbicides associated with the list, refer to the family classification in Appendix A.

Toxicity Classes

I = Highly toxic; a pinch to 1 tsp.; LD_{50} = 1-50 mg/kg

II = Moderately toxic; 1 tsp. to 2 tbls.; LD_{50} = 50-500 mg/kg

III = Slightly toxic; 1 oz. to 1 pt. or 1 lb.; LD_{50} = 500 - 5000 mg/kg

IV = Almost non-toxic; 1 pt. to 1 qt. or 2 lbs.; LD_{50} - over 5000 mg/kg

Chemical Family	Toxicity Class
acetanilides	II and III
aliphatic carboxylic acids	II and III
amino acids	III
benzoic acids	III and IV
benzonitriles	II and III
bipyridiliums	I and II
carbanilates	III
dinitroanilines	III
diphenyl ethers	III
inorganic compounds	III
organic arsenicals	II and III
phenols	I
phenoxy compounds	
acetic	II and III
butyric	III
propionic	II and III

Chemical Family	Toxicity Class
phthalic acids	II and III
pyridines	III
pyridazinones	III
thiocarbamates	III
s-triazines	II and III
as-triazines	III
triazoles	II and III
uracils	II and III
ureas	III

B. LD$_{50}$ VALUES

Toxicity is the relative ability of a substance to cause poisoning. The toxicity of a given poison to an animal varies with species, as well as age, sex, nutritional condition and the route of exposure (internal or dermal).

The basis measure used to express acute toxicity of a pesticide is its LD$_{50}$, which is the average lethal dosage (LD) per unit of body weight required to kill one-half (50%) of a population of test animals. The usual test animals are white rats, but may be mice, rabbits, and sometimes dogs. The most common LD$_{50}$ is the acute oral toxicity, that is, the single internal dosage necessary to kill half of the test animals.

The LD$_{50}$ value allows us to judge the relative acute toxicity of different chemicals. Low LD$_{50}$s are more hazardous than chemicals with high LD$_{50}$s. However, the LD$_{50}$ of a chemical to a rat is unlikely to be the same for humans or other animals.

The acute oral toxicity does not represent the full range of hazards of a chemical. It represents only the immediate toxicity of an internal dosage. The oral LD$_{50}$ does not indicate the chronic and cumulative effects of the chemical or potential for any skin absorption or irritation. Few herbicides are absorbed rapidly through the skin and most herbicides do not accumulate in the body to a toxic level. However, some do cause skin irritation. The potential health effects from long term, repeated exposure is not well known for most pesticides. The fact that a herbicide has a low toxicity does not mean that long term exposure will not cause adverse heath effects. Use of protective clothing and respirators is therefore important.

LD$_{50}$ values are expressed in terms of milligrams of chemical per kilogram of body weight (mg/kg). Some conversion factors to convert to common terms are:

$$1 \text{ ounce} = 28.38 \text{ grams} = 28,380 \text{ milligrams}$$

$$2.2 \text{ pounds} = 1 \text{ kilogram} = 1,000 \text{ grams}$$

An LD$_{50}$ of 1,000 mg/kg is equivalent to three ounces of material per 180 pounds of body weight, while LD$_{50}$ values of 100 mg/kg would be 0.30 ounces per 180 pounds. The toxic dose depends on body weight. It would take only one-third of this amount to kill a 60-pound child and five times as much to kill a 900-pound animal.

LD_{50} values are durived using only the active ingredient on the test animal. If a pesticide only 50 percent active ingredient, it would take two parts of the pesticide to make one part of the active ingredient. In some cases, inert ingredients mixed with the active ingredient for formulating a pesticide may cause toxicity to differ from that of the active ingredient alone. For example, the LD_{50} of 2,4-D acid is 320 mg/kg, while that of the ester formulation is 500 to 600 mg/kg.

The acute oral LD_{50} values for the active ingredient of some common herbicides are given in the table below. Remember, the lower the LD_{50} value, the greater the toxicity. A common standard for comparison might be aspirin, which has an LD_{50} value of 1,200 mg/kg.

LD_{50} VALUES OF SOME COMMON HERBICIDES

Common Name	Acute Oral LD_{50} mg/kg	Test Animal
Acrolein	46	rat
Endothall, (acid)	51	rat
(sodium salt)	190	rat
(amine salt)	206	rat
Dicamba (acid)	2900	rat
Dinoseb (DNBP)	58	rat
Paraquat	120	rat
Picloram	8200	rat
2,4-D (various formulations)	300 - 1000	guinea pigs, rats, & rabbits
2,4,5-TP	850	rabbit
MCPA	800	rat

PERENNIAL WEEDS IN MONTANA

Control of perennial noxious weeds should be of concern to every landowner in Montana. A combination of good farming and ranching management practices, cultivation, mechanical and cultural methods, biological control when available, and chemicals will continue to aid in the control of noxious weeds. Below is a brief description of the most serious noxious weeds threatening Montana's lands. Those marked with an asterisk (*) are not currently found in Montana or are not widespread in the state. Management of these potential threats should include survey, detection and eradication when found. For specific control information on all weeds refer to current Montana State University Extension Service publications. For color plates and a more complete description of these weeds refer to publications found in Appendix B.

A. ASTER FAMILY (Asteraceae)

1. Diffuse knapweed (*Centaurea diffusa*)

Diffuse knapweed is a biennial or short-lived perennial forb that grows to a height of 18 inches. It has a taproot and only one or very few stalks and is highly branched. The tip of each branch has a single flower head. The flowers are most commonly white with the upper portion of the bract fringed with spines. Often the outer most flowers are sterile. The bracts are yellowish green with a light brown margin. Seeds are small achenes, dark brown, with faint pale brown or ivory lines.

Diffuse knapweed grows well in dry sites and is found on waste grounds, fields, and along roadways in many areas of western Montana. The most serious infestation is located near East Helena.

Figure 1. Diffuse Knapweed

A. Plant Habit
B. Young Rosette
C. Leaf
D. Flower Head
E. Flower
F. Achenes

2. Spotted Knapweed (*Centaurea maculosa*)

Spotted knapweed is a perennial reproducing by seed. The stems are erect with slender, wiry branches, rough and hairy, and approximately one to three feet tall. Leaves are alternate with deep, narrow divisions and a rough, hairy surface. Flower heads are clustered and are numerous at the top of the stems. Flowers range from pink to purple and the outer bracts are tipped with stiff black, comb-like margins. Heads are 1/2 to one inch in diameter. The seed is an achene, brownish with one side notched near the base. There is a short tuft or bristles at the tip end and the seeds are approximately 2 mm long.

Spotted knapweed was introduced from Europe. It is often found in dry gravelly or sandy pastures, old fields, and along roadsides. It readily invades pastures and can take over nearby range. Spotted knapweed is found in every county in Montana but the heaviest infestations occur in the western part of the state.

Figure 2. <u>Spotted Knapweed</u>

A. Plant Habit
B. Enlarged Leaf
C. Flower Head
D. Disk Flower
E. Achenes

3. Russian Kanpweed (*Centaurea repens*).

Russian knapweed is a bushy, branched perennial plant reproducing by seed and underground rhizomes. The roots are characteristically black in color and have a scaly appearance. The stems are erect, two to three feet tall, branched at the base, ridged and have a dense gray hair-like covering. The basal leaves are hairy and the upper leaves are small and linear with smooth edges. The intermediate leaves have slightly toothed margins. The flower bracts are parchment textured, without the spine margins. The flowers are 1/2 inch wide, rose to purple heads and solitary on the ends of leafy branches. The seeds are grayish to yellow, smooth, flattened, oval, and about 1/8 of an inch long. The flowers generally bloom from June to August.

Russian knapweed was introduced from southern Russia and Asia. It grows in pastures, grain fields, cultivated fields, meadows, waste places, roadsides, and irrigation ditches. It is found throughout Montana. Once established it will completely replace other vegetation.

Figure 3. <u>Russian Knapweed</u>

A. Plant Habit
B. Head
C. Bracts
D. Flower
E. Achene
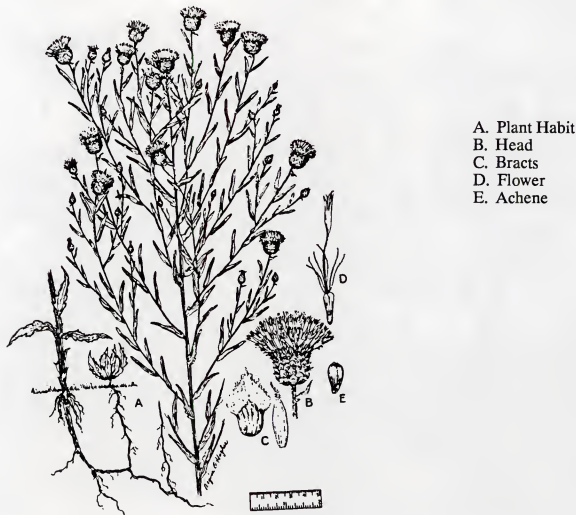
4. Yellow Starthistle (*Centaurea solstitialis*)*

Yellow starthistle is commonly a winter annual but it can germinate and grow to maturity in one season. The plant is gray green in color with cottony hair on the leaves and stems. It reaches a height of one to three feet, is branched, and has a yellow flower on the end of each branch. The leaves are narrow with the base of the leaf extending along the stem, giving them a winged or ridged appearance. The flower is bright yellow and has long, sharp, rigid spined bracts surrounding each flower. Two types of seeds are produced; light colored with bristly awns and dark with no bristles.

Yellow starthistle is found in cultivated and fallow fields, pastures, rangelands and waste places. It can invade range and pasture and competes well with existing vegetation. It crowds out existing grasses where moisture is limited and where grasses are weakened from overgrazing. It produces a toxic chemical that can cause death in horses and the spines can cause serious injury to grazing animals. It has been reported in Montana in Ravalli, Gallatin and Liberty counties. It is a serious problem in Idaho and Washington. It should be eradicated when found in Montana.

Figure 4. Yellow Starthistle

A. Plant Habit
B. Involucre
C. Flower
D. Achenes

5. Rush Skeletonweed (*Chondrilla juncea*)[*]

Rush skeletonweed is a taprooted, herbaceous perennial plant that overwinters as a compact rosette resembling an immature dandelion. The plant bolts in early spring. The flower stalk is one to four feet, and nearly leafless with spreading side branches. Stem leaves are narrow and linear. The flowers are yellow, 3/4 of an inch in diameter, and composed of seven to fifteen individual florets. An individual plant may produce up to 20,000 seeds. Each seed is attached to a light pappus, similar to the dandelion. Seeds have no dormancy and remain viable for only 28 months under normal environmental conditions. Taproots may extend to soil depths of seven feet and produce lateral roots which give rise to satellite plants. Cut plant surfaces exude a milky-white, latex sap.

Rush skeletonweed generally inhabits well-drained, light soils along roadsides in rangelands, grain fields and pastures. Soil disturbance aids establishment. It presently infests several million acres of rangeland in Idaho, Oregon, Washington, and California. It is a potential problem in cropland areas with light textured soils. It has caused an estimated $30,000,000 loss in Australian wheat producing areas. It is not currently found in Montana and detection and eradication programs should be initiated for the state. Cooperative detection programs have been developed for the Pacific Northwest.

Figure 5. <u>Rush Skeletonweed</u>

6. Canada Thistle (*Cirsium arvense*)

Canada thistle is a perennial plant reproducing by creeping horizontal roots and by seed. The extensive roots are fleshy and send up frequent new shoots. The stems are erect, hollow, smooth or slightly hairy, up to four feet high and branched at the top. The plants are leafy but no wings or spines occur on the stem. The wavy leaves are oblong to lance shaped and vary from irregular and deeply cut, to spiny toothed on the margins, to almost smooth with few or no spines. The color is usually bright green but the upper surface varies from dark to light and the leaves are sometimes very light green and slightly hairy on the underside. The flowers are numerous, small, compact, and vary from light lavender or white to rose-purple. There are many flower heads clustered together on the ends of branches. Canada thistle flower heads often appear much smaller than most other thistles. The bract on the heads are not spiny. The plant is dioecious, with male and female flowers produced on separate plants. Seeds are oblong, flattened, curved, smooth, dark brown, and approximately 1/8 inch long.

Canada thistle is an introduced species from Eurasia and grows throughout the northern half of the United States and north into Canada, from British Columbia to Quebec. It can infest all crops, pastures, meadows, and waste places, growing well in rich, heavy soils. Canada thistle is a serious threat to cereal crops in Montana. Wheat yields have been reduced from 15 to 60 percent in infested areas.

Figure 6. Canada Thistle

A. Plant Habit
B. Head
C. Flower
D. Achenes
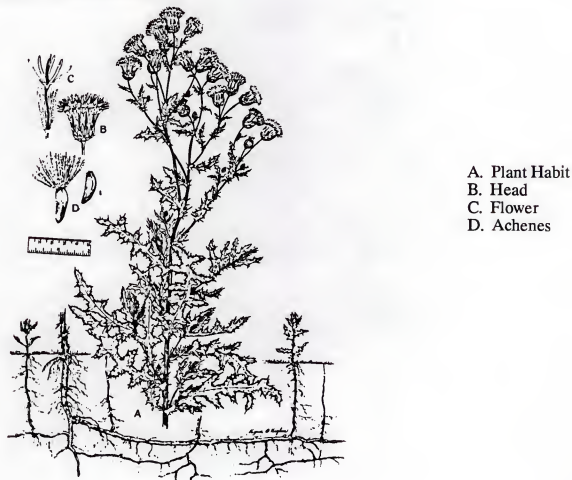
7. Common Crupina (*Crupina vulgaris*)*

Common crupina is a winter annual that reproduces by seed. It is closely related to the knapweed species. The cotyledon leaves are large, thick and dark green. They generally germinate in the fall when moisture is adequate and form a basal rosette. The true leaves are finely divided. A dense, fibrous root system develops quickly once the seedling is established. The plants overwinter as compact rosettes. In the spring the plant bolts and has a main flower stem from one to four feet tall. Leaves are alternate the length of the stem and are finely divided, lace-like leaflets. Stiff hairs on the leaf surface give them a sticky feel. Flowers are lavender to purple and are 1/2 inch long. Plants produce one to five seeds. Seeds (achenes) are large, cylindrical, tapering slightly to a blunt end. They have a dark, stiff pappus at the basal end. Dense, fine hairs cover the seed, giving it a black to silver color.

Common crupina is generally found on well-drained, rocky to silty loam soil in pasture or rangeland. Infestations start in disturbed areas or sites with sparse vegetation. It is a recent introduction and is currently on the federal noxious weed list. Detection and eradication programs are underway in the western United States in cooperation with the Animal and Plant Health Inspection Service (APHIS). Current infestations are found only in three counties in Idaho. An effort must be made to keep this weed out of Montana.

Figure 7. <u>Common Crupina</u>

8. Tansy Ragwort (*Senecio jacobaea*)*

Tansy ragwort is a biennial or short-lived perennial plant. Most seeds germinate in the fall, forming a rosette the following year, with flower and seed formation the next year. If the plant is cut, pulled or broken the second year this damage results in regrowth and blossoming during the third year. Tansy ragwort has daisy-like golden flowers with a long blossoming period. The rosettes have irregular, lobed leaves with a visible blade region near the tip. The stems are one to six feet high. The leaves, five to nine inches long, are attached directly to the main stalk. Leaf color may vary from light to dark green. The plant spreads principally by seeds, and individual plants may have as many as 150,000 seeds.

Tansy ragwort is a native of Europe. It grows well in pastures and disturbed areas on a wide range of soil types. It can survive under most soil moisture conditions and does well through the northwest area. Hot, dry summer and very low (-20 degrees) winter temperatures do not adversely affect this plant. The plant is toxic to both cattle and horses, and to some extent sheep. Alkaloids found in all parts of the plant cause irreversible liver damage. This plant is currently one of the most serious weed problems in Oregon and is also found in northern California, western Washington and British Columbia. It is found in limited areas of Montana and detection and eradication should be attempted.

Figure 8. Tansy Ragwort

A. Plant Habit
B. Flower Head
C. Ray Flower
D. Disk Flower
E. Achenes (ray flower)
F. Achenes (disk flower)
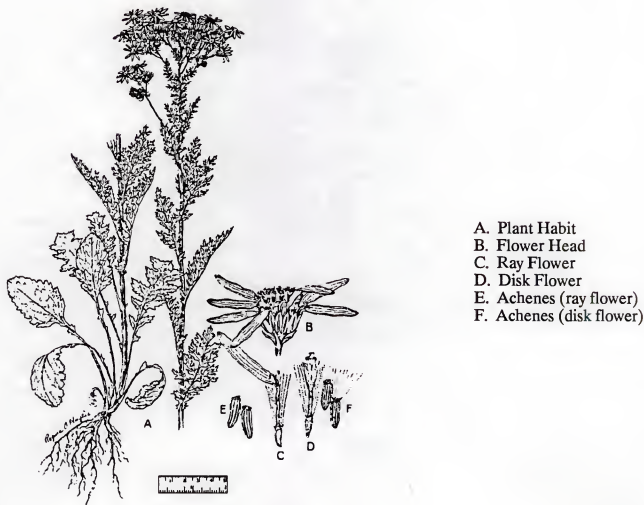
B. MORNINGGLORY FAMILY (*Convolvulaceae*)

1. Field Bindweed (*Convolvulus arvensis*)

Field bindweed is a viny, weak-stemmed, persistent perennial weed. It reproduces from an extensive rhizome system and abundantly produced seeds. The plant forms a mat on the soil surface with prostrate stems two to seven feet long that can climb short distances. The roots may extend 20 to 30 feet into the soil. The leaves are dull green and vary in size and shape, depending on soil fertility and moisture. Characteristically, they are ovate oblong with acute spreading basal lobes. The leaves have short leaf stalks that alternate on the stem. The plants flower from May to August and the flowers are white to light pink in color, funnel-shaped and borne on slender one to two inch stalks in the leaf axis. A pair of narrow, pointed leaflike structures (bracts) are found on the flower stalks 1/2 to one inch below the flower. The seed pod is round, pointed, light-brown, and contains four seeds. The seeds are dark-brown with a roughened surface, three-angled, and 1/8 to 1/5 inch long.

This plant was introduced from Eurasia and is now found throughout the United States except in the extreme Southeast and a few areas in the Southwest. It grows well under most cultivated conditions as well as in all uncultivated and waste places. It is extremely difficult to eradicate because of it's low growth and widespread, deeply penetrating root system. It is a serious problem in cropland in Montana.

Figure 9. <u>Field Bindweed</u>

A. Plant Habit
B. Rootstock
C. Leaf Variation
D. Flower
E. Capsule
F. Seeds

C. MUSTARD FAMILY (*Brassicaceae*)

    1. Dyers Woad (*Isatis tinctorial*)*

Dyers woad is a perennial, biennial or annual forb reproducing by seeds and from roots. Plants may grow from one to three feet tall and have a smooth, bluish-green color. Lower leaves clasp the stem with ear-like projections. The yellow flowers are very small and form a flat-topped inflorescence. The seed pods are about 1/2 inch long, winged like a maple seed and turn black when mature.

Dyers woad is native to Europe. The name comes from Germany where dye was extracted from the purplish black seed pods. It is a serious weed problem in both Utah and Idaho and can be found in several locations in Montana. It spreads readily by seed from roadsides to rangeland and crops. Detection and eradication is imperative for Montana.

Figure 10. <u>Dyers Woad</u>
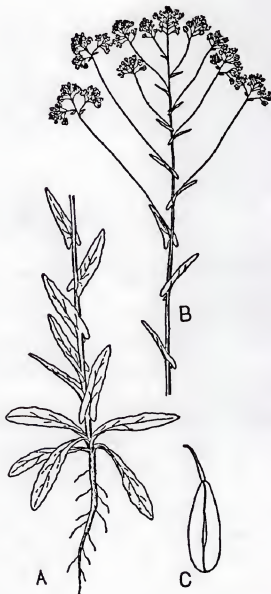
A. Plant Habit
B. Plant Habit
C. Fruit

2. Whitetop (*Cardaria draba*)

Whitetop (hoary cress) is a perennial reproducing by seed and rhizomes. It has numerous erect stems one to two feet high that are branched at the top. An extensive root system spreads both horizontally and vertically with frequent shoots arising from the root stock. The plant appears gray green from the dense fine hairs on the leaves. The leaves are simple, alternate, oblong, toothed and the upper leaves have a broad clasping base. The flowers are white, four-parted, about 1/8 inch wide and borne in flat-topped clusters. Seed pods are slightly flattened, two-valued, heart-shaped with a prominent persisting style. The seeds are oval, slightly flattened, granular with reddish-brown seed coats.

Whitetop is naturalized from Europe and found throughout the United States except in the Southcentral area. It is found in pastures, cultivated fields, hay fields, meadows, waste places, and roadsides. It is most common in western and central Montana.

Figure 11. <u>Whitetop</u>

A. Plant Habit
B. Flower
C. Silicle
D. Seeds
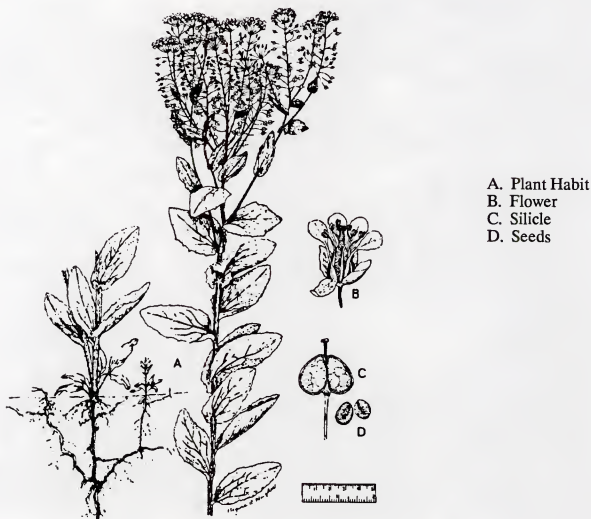
D. SPURGE FAMILY (*Euphorbiaceae*)

1. Leafy Spurge (*Euphorbia esula*)

Leafy spurge is a perennial, reproducing by seed as well as an extensive underground rhizome system. The heavy running roots are woody, persistent and widespread and give rise to dense colonies of the plant. Pink buds on creeping rhizomes give rise to roots and shoots every few inches. The stems are erect, smooth, and branched at the top. The entire plant is a dull green color with milky juice and grows about two feet tall. The leaves are alternate and irregularly spaced along the stem. There is a whorl of lance-shaped leaves at the base of the umbel. The flowers are inconspicuous and are formed above pairs of rounded floral bracts on repeated forking stems arranged in a flat-topped umbel. When in full bloom the entire umbel, including the bract, turns a bright greenish yellow. The seed pods are on a short stalk from the cup-like base and are three angled. There are three ovoid, smooth, light gray to brownish seeds in each pod.

Leafy spurge is an introduced plant from Europe. It is found in most of the northern United States and Canada. It grows readily in waste areas, pastures, roadsides, cultivated fields and sandy banks. It can be toxic to cattle, but sheep do well eating it. Leafy spurge is one of the most persistent noxious weeds in Montana. It is found throughout the state over a wide habitat and is extremely difficult to control.

Figure 12. <u>Leafy Spurge</u>
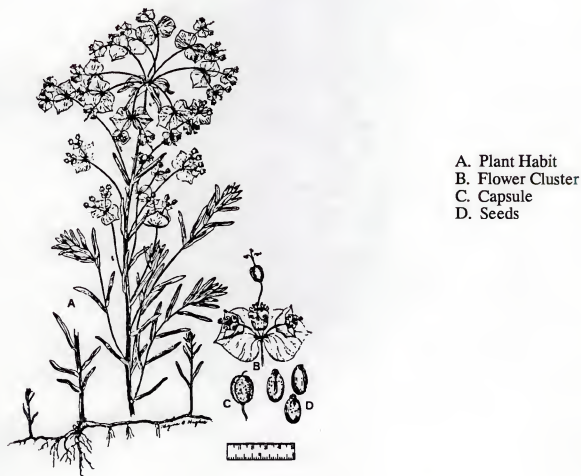
A. Plant Habit
B. Flower Cluster
C. Capsule
D. Seeds

E. ST. JOHNSWORT FAMILY (*Hypericaceae*)

1. Goatweed (*Hypericum perforatum*)

Goatweed is a perennial forb reproducing by seed and from rhizomes. Stems are smooth, branched, about three feet tall and woody at the base. The opposite leaves are elliptic to oblong and have small, glandular dots. The orange-yellow flowers are about 3/4 inch in diameter and five petaled. The three parted seed pods are round, pointed, and contain many seeds.

Goatweed is common in dry pastures, rangelands, neglected fields and along roadsides in western Montana. It is not readily grazed by livestock and causes photosensitization in light skinned animals. It should be regarded as a poisonous plant. Control is difficult.

Figure 13. St. Johnswart

A. Plant Habit
B. Enlarged Leaves
C. Flower and Bud
D. Capsule
E. Seeds

F. SNAPDRAGON FAMILY (*Scrophulariaceae*)

1. Dalmation Toadflax (*Linaria dalmatica*)

Dalmation toadflax is a perennial, reproducing by seeds and creeping rootstocks. The plants are erect, about two feet tall, pale green and have showy, yellow flowers. The spurred flowers are tinged with orange and are about one inch long. The leaves are broad, heart-shaped, and clasp the stem.

Dalamation toadflax is a native of the Mediterranean region. It is found scattered throughout the northern and western United States. It is an escaped ornamental found along roadsides and near dwellings, spreading to valleys and sagebrush flats. Large infestations are found in several Montana counties.

Figure 14. <u>Dalmation Toadflax</u>

A. Plant Habit
B. Flower
C. Capsule
D. Seeds
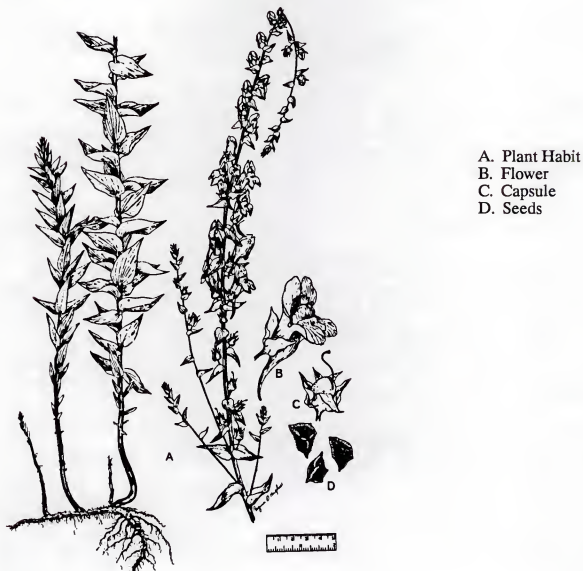
CHAPTER IX

INTRODUCTION TO WOOD TREATMENT

A. <u>DETERIORATION OF WOOD BY FUNGI, INSECTS AND OTHER AGENTS</u>

Decay may be thought of as a reversal of the wood growing process. During growth, the action of sunlight on the leaves of a tree, combined with **water** and **carbon dioxide,** form **sugars** (mainly **glucose**). This sugary solution is transmitted to all growing parts of the tree where it is converted chiefly into **cellulose**, which forms the cell walls. Some of the sugars combine to form **starch** used as a reserve form of "stabilized glucose" to restart the growth processes when needed, usually in the spring.

During decay, cellulose and starch first are broken down into sugars and eventually into carbon dioxide and water. These sugars, in wood substance, are a source of food which attract decay fungi and some insects.

Only a relatively small number of insects and fungi are classified "wood destroyers". They produce enzymes which can digest wood cellulose and convert it to a usable form of sugar. Then they feed on the sugars to obtain energy for further growth and other life processes. By contrast, termites chew wood into very fine particles after which digestion takes place by enzymatic action within their stomachs. The sugar is then similarly available as food for their bodies.

B. <u>NATURAL DURABILITY</u>

Natural durability of wood is mainly because of the presence of substances called **extractives** in the heartwood. Extractives refer to a collection of chemicals which form when the tree is growing, but which are harmful to the sensitive cambium. To protect this growth zone, the harmful substances are passed (like transporting liquid toxic waste through pipes) along the rays and deposited in the dead cells of the heartwood. Not surprisingly, extractives are often toxic to insects and fungi as well as to the cambium, so they act like preservatives. The type and quantity of extractives are characteristic of each wood species, giving it a greater or lesser degree of natural durability, and sometimes a distinctive color and odor of its own.

The **heartwood** of several species of wood have natural, high resistance to decay fungi. However, the sapwood of all known tree species is very susceptible to decay, regardless of any natural resistance of the heartwood (See **Table 1**). Unless sapwood is entirely removed or impregnated with preservatives, decay may occur even in durable species. Also, some of these very durable species are becoming scarce and costly, as with mahogany and teak. The high cost of this wood practically rules out their use solely for natural durability applications (high decay hazard situations). Scarcity limits the use of many such species to veneers and small parts so that the wood of each tree will provide optimum raw material utilization and profitability.

Table 1 Natural Durability of Common Wood Species: The following code letters and descriptions of natural durability apply to the heartwood of the species listed. Sapwood has no significant natural durability, regardless of species, age or growth site.

Durability Code	A	B	C	D	E
Description	Very Durable	Durable	Moderately Durable	Non-Durable	Decays Readily
Typical useful life of a small post in the ground (years)	Over 25	15-25	10-14	5-9	1-4
		HEARTWOOD OF:			SAPWOOD OF:
		(Species)			
Softwoods	None	Cedars, Redwood, Bald cypress, Yew	Douglas fir, Pines: East,White Longleaf, Slash, Larches, Tamarack	Firs Hemlocks Other pines Spruces	All Species
					HEARTWOOD OF
					None
		HEARTWOOD OF:			SAPWOOD OF:
		(Species)			
					All Species
Hardwoods	Black locust, Green-heart	Black walnut, Central American mahogany, Chestnut, White Oak		Elms, Hickories, Maples, Red Oaks, Sweetgum	HEARTWOOD OF
					Alder Ash Aspen Balsa Basswood Beech Birches Cottonwood Hornbeam Horse-Chestnut Poplars Sycamore Willows

When virgin forests were available, naturally durable heartwood timber was widely used. As these large trees were harvested, they were replaced by trees with a greater proportion of sapwood with low natural durability. The need for greater durability gave rise to the wood preservation industry. The use of naturally durable wood has declined and will continue to diminish. Our future need for durable wood products will be provided by forests replanted with fast growing trees of low natural durability, but the wood from these trees will be treated with preservative chemicals for use under high-risk decay situations.

Wood preservation can be defined as the process of adding adequate quantities and concentrations of toxic or repellent substances to a wood product to upgrade its resistance to biological attack and making it more durable. All wood preservatives recommended for ground contact use in the U.S. are capable of protection against wood destroying organisms.

C. ROTTING FUNGI

Depending on the environment and other circumstances, wood may be attacked by one kind of fungus or by a variety of fungi. For example, the part of a fence post just below the ground will probably be attacked, in sequence, by bacteria, then "soft rot" fungi, then "brown-rot" or "white-rot" fungi, until that part of the post is so decayed that it falls over. The succession of fungi, and the way in which they attack the wood cells, is complicated. What we should know is that unprotected wood will deteriorate within a few years, sometimes suddenly. When both **fungi** and **termites** attack wood, even more rapid failure can occur.

The greatest fungal risk to untreated wooden items comes when they are used in or on the ground. Another risk to unprotected wood is its use in fresh or slightly salty "brackish" water (as near the mouth of rivers), inside water cooling towers and in very humid environments like greenhouses. For many construction purposes, wood will generally be too dry for successful fungal attack.

There are **five conditions** essential for fungal decay to occur:

> (1) **Source of moisture.**
>
> (2) **Favorable temperature (50 degrees - 90 degrees F).**
>
> (3) **Source of "food" for the fungus** (e.g. wood components - cellulose, starch, hemicellulose, lignin).
>
> (4) **Oxygen.**
>
> (5) **Fungal source.** The spores ("seeds") of fungi are abundant almost everywhere in nature. We can expect decay if all four conditions are present (See **Figure 15**).
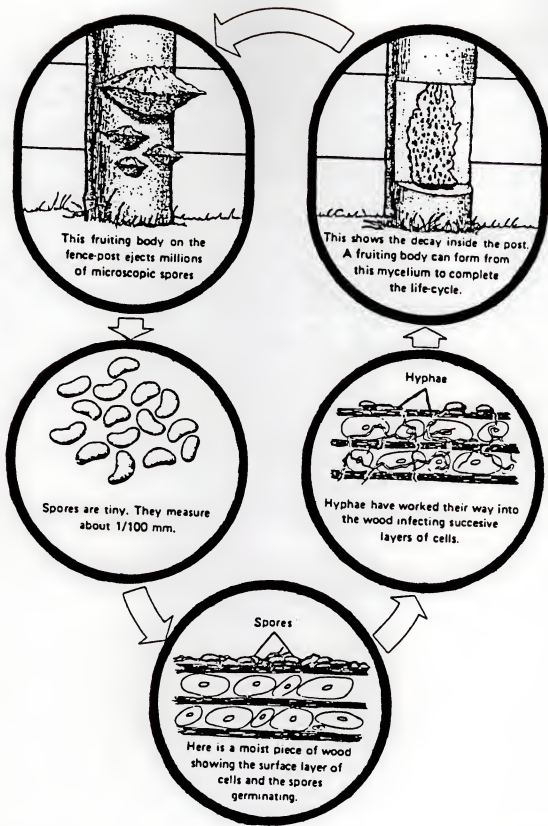
Figure 15. Life cycle of a wood-rotting fungus.

D. STAINING FUNGI, SURFACE MOLDS AND MILDEW

Staining fungi, which live on the starch in wood cells, may discolor the sapwood entirely or in patches without breaking-down the cellular structure of wood. Most common are the sapstain or bluestain fungi which turn the normal color of wood a bluish or gray-black color. Although blue-stained lumber may experience a reduction in impact strength or shock resistance, other important properties such as compressive and bending strength are not affected. However, it is important to prevent sapstain because it spoils the appearance of lumber, lowers its grade and reduces its commercial value. Sapstain fungi may also provide an environment in the wood that may be conductive to attack by wood destroying fungi. Sapstain is best prevented by prompt kiln-drying or by dipping or spraying with a chemical solution immediately after green wood is sawn or planed.

Discoloration of wood surfaces by molds and mildew is superficial, so the discoloration can be removed by brushing or planing. Although their presence does not appreciably affect the strength of wood, the water absorptiveness of infected wood is greatly increased. This condition renders the wood more susceptible to attack by decay fungi. Fortunately, molds and mildew growth can be prevented by promptly drying green or moist wood and keeping it dry (below 19% M.C.). Pressure applied preservatives or other chemical treatments will also effectively prevent their growth.

CHAPTER X

WOOD PRESERVATIVES

A. CHEMICAL PRESERVATIVES

The oldest preserving technique for preventing wood decay was probably **charring**, first done over 4,000 years ago by plunging round stakes in fire. The Temple of Diana, at Ephesus in Ancient Greece, was built on charred wooden piles.

Throughout the centuries, new chemicals were continually tested for qualities suited for wood preservation. The Greeks poured oil into bored holes to preserve the pillars supporting buildings; **vegetable** and **mineral oils** were used to preserve wood by several early peoples, including Romans, Chinese, Burmese, Greeks and Egyptians.

Impregnation of wood by chemicals using vacuum and pressure started in 1831 with a French invention, which made it possible to test thousands of chemicals and preservatives. This testing of new chemical formulations is a never-ending process. Despite this effort, very few successful, new products have emerged suitable for today's wood preserving needs.

Wood preservatives are toxins and/or repellents to fungi and insects and are classified as pesticides. The use is regulated by FIFRA and MPA. Some wood preservatives are labeled as restricted use pesticides and therefore require applicator certification for purchase and use.

B. CARRIER LIQUIDS OR SOLVENTS

Preservatives are used in liquid form. They rely on **solvents** to carry the preservative chemicals into the wood during impregnation. Each wood preserving chemical has unique properties of its own, like solubility, boiling point, etc. In practice, each is linked to one or more particular solvents, which suit the physical properties of the preservative chemical. **Table 2** shows how carrier liquids (or solvents) are often classified, and which major wood preservative chemicals are commercially used with each carrier.

As the table shows, **creosote** is unique in that it acts as both preservative and carrier. This is because creosote is a very complex liquid mixture of chemicals recovered from the heating of coal or wood in the absence of air; only a few of these chemicals are good wood protectors, the others act as carriers or fillers.

C. MAJOR CHEMICAL PRESERVATIVES

Detailed descriptions of the chemical and physical properties of chemical preservatives are published annually in the American Wood Preserver's Association (AWPA) Standards.

  1. **Creosotes**

  These are brownish-black, oily liquids, with a heavy "smokey" smell. Creosotes and other **tar oils** are produced when a naturally occurring carbon-rich substance (such as coal, lignite or wood) is heated without air. The tars and creosotes vaporize from the hot mass and are recovered by condensation (See **Table 3**).

Table 2. Primary solvents used with wood preservatives.

Key to table: X = major use
                o = some use
                * = in dispersed or emulsified form

PRESERVATIVE CHEMICAL	MAIN LIQUID CARRIERS OR SOLVENTS				
	Creosote	Heavy Petroleum Oil	Light Petroleum Solvent	Water	Amonia and Water
Creosotes	X	X			
Pentachlorophenol (PCP)	o	X	X	o*	o
Chromated Copper Arsenates (CCA)				X	
Amoniacal Copper Arsenates (ACA)					X
Copper Naphthenate		o	o	o*	
Zinc Naphthenate		o	o	o*	
Copper-8-Quinolinolate (Copper-8)			o	o*	
Bis-(Tri-N-Butyltin) Oxide (TBTO)			o		
Behavior of Carriers After Treatment	Little evaporation; most remains in wood permanently	Little evaporation; most remains in wood permanently	Most evaporates from wood	Water evaporates completely	Water and amonia evaporate completely

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Table 3. Summary of coal tar creosote properties: Advantages and Disadvantages

PROPERTY	ADVANTAGES	DISADVANTAGES
Preservative function	Excellent protection against fungi, insects and most marine borers	Poor protection from *Limnoria tropunctata* in warm water marine situations.
Color and surface properties	Treated wood is dark brown Mixtures with heavy oil are lighter brown	Oily; cannot be painted over or glued. Surface smears, and causes stains on clothes and burns on skin.
Smell	--	Strong, not suitable for indoor use. Harmful to growing plants.
Heat stability	Excellent, suitable for thermal and Boultonizing processes. (Heating is necessary to reduce viscosity)	--
Fire risk	--	Creosote will ignite so care must be taken when heating it.
Weight of treated wood	--	Weight increases of 25-50%. Increases trucking costs.
Other properties	Restricts moisture pickup and reduces weathering	--
Safety	--	See Chapter VII

Creosotes are probably the oldest, commercial wood preservatives. Creosotes are viscous (thick) liquids. At ordinary temperatures, they do not soak into wood to an effective degree. That disadvantage was rectified in 1838 when John Bethell introduced the Bethell or Full Cell Process which uses pressure to force hot creosote into the wood cells.

The main form of creosote used in North America is a by-product from the production of coke from coal. The coke is used in steel manufacture. This creosote is called **Coal Tar Creosote.**

Coal tar creosote is heated before being pressurized into wood. Sometimes it is mixed with other coal-distillation by-products such as tar oils or with heavy petroleum oils. AWPA Standards list the allowed combinations of ingredients.

The successful use of coal tar creosote since the Bethell Process was invented has been far reaching. All kinds of uses for wood were made possible, even species which had little natural durability could be used. Without creosote, it is hard to imagine how the North American railroads could have been built. Creosote treated cross-ties, mainly of Douglas-fir, southern yellow pines and the oaks have given 30 to 50 years of service. The electrification of rural areas, telephone networks, trestle bridges for road and railcrossings and fencing to contain livestock are largely the result of wood treated with coal tar creosote.

Typical use of creosote

Poles - utility, farm buildings
Piles - land, fresh or sea-water
Docks - piers, timbers and decking in harbors
Fencing - posts and rails, farms and estates
Cross-ties - railroads
Bridges - support and decking timbers
Lumber and timbers

Creosote is unsuitable for

Use inside some buildings where people live or work
(Federal Register, EPA Jan. 10, 1986).
Most situations where there is contact with people or animals.
In contact with or near food.
Wood surfaces which requires paint.

2. **Pentachlorophenol (PCP or Penta)**

Pentachlorophenol is a crystalline, white solid made in a controlled chemical process. The preservative ability of Penta was discovered around 1935, and it has since developed into a successful wood preservative (See **Table 4**).

Pentachlorophenol is usually dissolved in either light or heavy petroleum oil, to produce wood preserving liquids. It can also be dissolved in water (as ammonium pentachlorophenate) or can be dispersed or emulsified using water as its carrier. Penta can also be added to creosote, petroleum oil mixtures to boost performance.

Pentachlorophenol preservative solutions impregnated into wood have a tendency to evaporate, causing **blooming.** Blooming is the formation of Penta crystals on the surfaces of treated wood as a result of exudation and evaporation of the solvent. This evaporation is minimized by the inclusion of a non-volatile liquid when an evaporating carriers or solvents are used. Protection from contact with the penta crystals can be accomplished by sealing the dried, treated surfaces with a coating of urethane, shellac, varnish or a latex, epoxy enamel.

Sodium pentachlorophenate, the water soluble form of **pentachlorophenol,** and the closely related **tetrachlorophenol,** have been widely used in anti-sapstain dips for treating lumber in sawmills. This kind of treatment and other uses of chemicals, not directly increasing the service life of wood, are not covered in this manual.

Typical uses of pentachlorophenol

Poles - utility, farm buildings
Cross-arms - utility poles
Piles - in soil
Fencing - posts and rails
Lumber and timbers
Bridges - support and decking timbers

PCP is unsuitable for

Most uses inside homes or offices.
Marine protection of wood.
Near livestock on farms.
In contact with or near food.

3. Chromated Copper Arsentates (CCA's)

Copper was known to have preservative properties long before the development and use of CCA's. Copper sulphate in water solution is a fairly inexpensive wood preservative, but two factors prevent its widespread use.

1.   It is very soluble in water, so tends to wash or leach out of the treated wood, leaving it unprotected.

2.   Copper sulphate protects wood from most fungi, but is ineffective against insects, such as termites, and a few "copper-tolerant" fungi.

The first disadvantage (solubility) was overcome by adding chromates to copper sulphate to "fix" the copper in the wood in an insoluble form. The second fault was corrected by including arsenates with the copper/chromate mix to control both insects and copper-tolerant fungi (See **Table 6**).

Table 4. Summary of pentachlorophenol properties: Advantages and Disadvantages

PROPERTY	ADVANTAGES	DISADVANTAGES
Preservative function	Excellent protection from fungi and insects.	Poor protection from marine borers.
Color and surface properties	PCP is colorless, and if applied in light petroleum solvent, or water-based carrier, will slightly affect wood color.	PCP can stain paints so a special primer may be needed. The use of light petroleum solvent is essential if wood is to be painted or glued.
Odor	--	Treated wood retains an irritating smell. Harmful to growing plants and humans in enclosed spaces.
Heat stability and fire risk	Good - heating PCP solutions is less common than with creosotes.	All oils will burn. Care has to be taken when heating them.
Weight of treated wood	If an evaporating carrier is used, weight increases after drying are negligible (1 to 20%).	Permanent weight increases 20 to 50% when heavy petroleum oil is used.
Other properties	PCP does not smell but, if used in a petroleum or cresote-based carrier, will acquire odor of the carrier. Can add a water repellent to improve weather ability.	Contact with treated wood can cause skin burns (especially if oily carrier used).
Safety	--	See Chapter XII

Commercial use of CCA preservatives began in the 1950's. They are marketed under several brand names and have become the most versatile of all wood preservatives. Their use is growing in North America, partly at the expense of creosote and pentachlorophenol. Also, more and more treated lumber is being demanded by specifiers and the Do-It-Yourself (DIY) market, as a replacement for creosote or penta preservatives.

The weight of wood may double after CCA treatment, but most of the additional weight is water which evaporates after drying. The permanent (weight) of CCA ozides is small, ranging from 0.7% to 1.8% because only 0.25 lb./cu. ft. is required for above-ground use, and 0.40 lb.cu. ft. is recommended for ground contact use.

As with most preservatives, wood properly treated with CCA shows no significant changes in strength properties. However, the use of high temperature and/or high pressure of long duration during treatment can reduce wood strength.

Treatment with CCA initially imparts an orange hue to the wood which then changes to pale green. Other colors may be obtained by the use of color additives before, during or after treatment.

Formulation Details

The AWPA Standards list three types of CCA which may be used interchangeably throughout the commodity specifications covered. These are **CCA Types A, B and C,** and their differences arise from historical rather than scientific or practical grounds. At present, Type C is most widely used (See **Table 5**).

Table 5. AWPA Standards.

CCA	Type A	Type B (nominal percent)	Type C
Copper Oxide	18.1	19.6	18.5
Chromium Trioxide	65.5	35.3	47.5
Arsenic Pentoxide	16.4	45.1	34.0
Total	100.0	100.0	100.0

Note that the copper content of the three types of CCA is similar. The differences lie in the balance between chromium and arsenic.

Table 6. Summary of Chromated copper arsenates properties, advantages and disadvantages

PROPERTY	ADVANTAGES	DISADVANTAGES
Preservative function	Excellent protection from fungi and insects and most marine borers.	Only moderate protection from *Pholad* marine borers. Will not prevent mildew.
Color and surface properties	Green-gray, weathering to silver-gray after some years. Can be painted, glued. Does not smear clothing or skin after seasoning. Additives to CCA can give wood a brown color	Natural wood color is lost.
Smell	No smell or vapors. Suitable for use indoors and near growing plants.	--
Heat stability	--	Breaks down from prolonged heat above 140 degrees F. Cannot be used in Thermal or Boultonizing Process.
Fire risk	None	Treated wood "glows" to destruction in fire.
Weight of treated wood	Negligible weight increase of l to 2% after wood has re-seasoned.	Weight increased temporarily by 20 to 90% immediately after treatment.
Other Properties	--	Swells wood on treatment, so some seasoning defects may occur on re-drying. Weathering is similar to that of untreated wood.
Safety	--	See Chapter XII

Typical uses for CCA preservatives

> **Buildings** - lumber on inside or outside of homes
> **Yard Use** - decks, patios, fencing, trellises, sheds, landscaping
> **Poles** - utility, barns for animal use, storage sheds
> **Piles** - in soil, fresh or sea water
> **Fencing** - posts, rails, boards and panels
> **Piers** - timbers and decking in harbors
> **Highway barriers** - post spacers

CCA is unsuitable for contact with food and for preserving railroad cross-ties. Creosotes and PCP in heavy petroleum oil provide greater cross-tie protection against cracking in wet/dry weather cycles.

Other Preservatives

There are many wood preservatives available. In specifying treated wood for a given purpose, refer to the AWPA Standards or Federal Specifications for acceptable preservatives and treatments. Several other preservatives used in the U.S. are discussed below.

4. Ammoniacal Copper Arsenate (ACA) (Waterborne)

This preservative is similar to CCA, but it does not use chromate as a fixing agent. Instead, **copper arsenate** is made soluble in water mainly by addition of **ammonia**. After treatment, the ammonia and water evaporate, leaving water-insoluble copper arsenate "fixed" in the wood. Treated wood has a blue-green to brown color, often uneven.

The ACA preservative (commercially known as **"Chemonite"**) was developed on the West Coast of U.S.A., and is mainly used there and in western Canada for pole treatments. It is usually rated equal in performance to CCA.

5. Copper Naphthenate

Copper naphthenate is made by reacting copper salts with **naphthenic acid** (a petroleum by-product). It is a viscous, dark blue-green liquid, soluble in petroleum solvents and should contain 6-8% copper by weight. It can also be produced in water-emulsifying form, but is normally dissolved in heavy or light petroleum oils.

This product is a good wood preservative for preventing decay, and has the advantage of being safe to use near growing plants (after any volatile solvent used has evaporated). Treated wood has a distinctive green color, but this fades in sunlight. It is used for greenhouse lumber, yard and landscape timbers, seed and mushroom boxes.

Disadvantages are its fairly high cost, lack of protection against termites, persistent "oily" smell, and poor ability to take paint or glue. Organic solvent versions are flammable.

6. Zinc Naphthenate (Volatile Petroleum Oil-borne)

Zinc Naphthenate is similar to Copper Naphthenate but is not as effective a fungicide. The zinc salt does have an advantage of being almost colorless.

7. Copper - 8 Quinolinolate (Water and Volatile Petroleum Oil-Borne)

"Copper-8" is the only preservative accepted in U.S.A. for wood which is to directly contact human food. Preservative solutions must be made using a well-refined, "odorless" solvent to avoid tainting food. Normally an equal weight of **Nickel 2-ethylhexoate** is added to the "Copper-8". The concentrated preservative chemical should contain **l.8% by weight of both copper and nickel.**

The product is expensive, but is the only product available for use on food pallets, wooden vehicle and container bases and in food processing equipment. The liquid is bluish-green and is flammable.

8. Tributyltin Oxide (Volatile Petroleum Oil-Borne)

Tributyltin Oxide, or **"TBTO"**, (Bis- (tri-N-Butyltin) Oxide) is a colorless, watery liquid with a sharp, retentive odor. The tin content, by weight, should be between **38.2% and 40.1%.**

This liquid is dissolved in light petroleum solvents and is flammable. It is mainly used in place of pentachlorophenol at concentrations of 0.5 to 1.5% TBTO, where improved paint or glue performance is needed. It is limited to above-ground use such as for millwork, and especially for external window or door components.

D. **POLE WRAPS & BRUSH ONS**

A variety of pole wraps (bandages), and brush-ons or paint-ons, are available on the market today. Many of the products contain pentachlorophenal (PCP) and other chlorinated phenols and are restricted use pesticides. They are not difficult to apply, but a few common sense safety measures should be taken when they are used:

> 1. Applicators must wear gloves impervious to the wood treatment formulations (eg. poly vinyl acetate (PVA), poly vinyl chloride (PVC), or neoprene) in all situations where dermal contact is expected (eg. during the actual application process and when handling freshly treated wood).
>
> 2. Applicators must wear long sleeved shirts, long pants and an impermeable apron during the application and mixing processes.
>
> 3. Applicators must not eat, drink, or use tobacco products during the application process .
>
> 4. Wash thoroughly after skin contact and before eating, drinking, use of tobacco products, or using restrooms.
>
> 5. Some products are corrosive and can cause irreversible eye damage and skin burns. A face shield or safety goggles may be required when using these products.

THE WOOD TREATING INDUSTRY

A. CHANGES WITHIN WOOD TREATING INDUSTRY

The 1980's brought several changes to the wood treating industry. Two of these changes are briefly discussed below.

1. Preservatives and Product Mix

Although no truly-new wood preservatives have come into widespread use for 20 or more years, there has been a shift in usage among the primary preservatives types: Creosote, PCP in petroleum oils, CCA and other waterbornes.

Creosotes and PCP are losing markets to CCA primarily for lumber and timbers. The principal reasons for this shift are reduced demand for some traditional treated products such as cross-ties, higher prices and increased environmental concern. Nearly all new treating plants being installed seem to favor the use of CCA or ACA preservatives.

The fast growth of CCA preservative use has been mainly the result of demand by the Do-it-Yourself market. There has been a trend towards CCA use in place of creosote for poles, fencing and piling. Also, the number of creosoted cross-ties needed by the railroads for replacements are much fewer than when the railroads were expanding.

There has been a similar trend of PCP market loss to CCA treatments, but this has been countered somewhat by the introduction of water-dispersible forms of PCP. These forms eliminate or reduce the need for petroleum oils, which, like all petroleum products, escalated in price in the 1970's, so the new forms of PCP are now being favored for some applications.

2. Aesthetic Demands

Until recently, treated wood was recognizable as a fairly rough, poorly finished, often dirty-looking commodity, which happened to be dark brown, green or natural colored, depending on the preservative used. Efforts are now underway to enhance the appearance of treated wood by improvements in surface cleanliness and color of the finished product.

Surface Cleanliness: CCA-treated wood is subject to dark mold growth, which looks like dirt on the surface. Additives can now be included with the CCA at the treating plant which prevent mold growth and give a cleaner looking, more attractive product.

Color: The availability of attractive brown shades of treated wood which is suitable for yard wood, without further coloring, has also helped increase demand.

Competition in the preservation industry is forcing treaters to look, not only at price and profit margins, but at quality as well. Fewer defects, better surface finish, color and cleanliness are all part of on-going product improvements.

CHAPTER XII

SAFETY AND THE ENVIRONMENT

A. HEALTH AND SAFETY FACTORS

The U.S. Environmental Protection Agency (EPA) made a detailed study of wood preservatives, to determine their risks to the environment, to treaters and to users of the treated wood. This study covered the three major-use preservative types: **creosotes, pentachlorophenol-based preservatives** and **arsenical preservatives** (CCA's).

The EPA initiated the study because it believed from existing evidence that all three classes of preservatives could damage the health of people and of plants and animals in contact with the preservatives or in close proximity to a treating plant. After six years of study, discussion and lobbying, EPA published its findings about the three types of preservatives in a final position document in July 1984.

EPA concluded that:

> 1. Each class of preservative studied was capable of adversely affecting the health of people who produced or used the treated wood, or other people, indirectly such as by vapors from treating plants and by contaminated rivers or ground water, etc.

> 2. Each preservative played a significant part in conserving timber resources, by preventing early decay of wood in homes, other buildings, fencing, poles, cross-ties, etc.

> 3. Ways could be found to allow the continued use of all three types of preservatives but tighter restrictions on handling, labeling and treatment site practices. The industry was also required (but this has since been made voluntary) to provide **Consumer Information Sheets (CIS's)** with all sales or deliveries of treated wood.

After further discussion between the EPA and the wood preserving industry, a detailed agreement was reached. The changes are intended to protect the treater, the end-user and the environment.

B. HUMAN HAZARD

The labels of wood preservatives for the pressure treatment of wood contain safety information for the user of the product. **Carefully study the label and any additional information supplied by the manufacturer or formulator to determine the safety equipment and procedures needed** to protect yourself and your employees. It is illegal to use preservatives in any manner inconsistent with label directions.

EPA classified the three principal wood treatment preservatives as restricted use pesticides based on evidence that: **creosote** causes cancer in laboratory animals and the increase of skin cancer has been associated with some workers occupationally exposed to creosote; **creosote** and **inorganic arsenicals** cause mutagenic effects (gene defects) in bacteria and laboratory animals; **pentachlorophenol** has produced defects in the offspring of laboratory

animals; a **dioxin** contaminate in pentachlorophenol has been shown to cause cancer in laboratory animals; and **arsenic** has been shown in epidemiological studies to be associated with cancer in humans who either drank water contaminated with arsenic or who breathed air containing arsenic.

Remember, the certified applicator licensed for use of restricted use wood preservatives at each plant or application location is responsible that the proper safety equipment be provided and employees be instructed as to its proper use in accordance with label instructions. EPA requirements for label instructions can change so the instructions provided in this chapter may not be the same for the formulation you are using. Always carefully read the label for the safe handling of the product you are using.

C. CONSUMER AWARENESS PROGRAM (CAP)

EPA is concerned that end users of preservative treated wood be informed about the limitations of use, and safety in handling these products. At present this is a voluntary program to be conducted by the wood treatment industry, but this and the details of the proposed program may change. AWPI, SAWP, and NFPA are to use their best efforts to implement this program. "The treated wood industry will develop a model **Consumer Information Sheet (CIS)** containing site precautions and safe working practices for each of the three types of treated wood. The CIS will serve as the main vehicle for conveying information about treated wood to consumers. The focus of the **CAP** will be on ensuring the dissemination of the **CIS** at the time of sale or delivery to end users". (Federal Register/Vol. 51, No. 7/Jan. 10, 1986).

D. ENVIRONMENTAL CONTAMINATION 1/

Pentachlorophenol

Pentachlorophenol is not uncommon in the aquatic environment. Circumstantial evidence, including the identification of pentachlorophenol in rain water, indicates that pentachlorophenol may occasionally be present in **ambient air.** Low levels of this compound have been detected in both **wastewater** and **surface water.** While the source of these residues is often unclear, it has been suggested that, in addition to direct contamination of water by pentachlorophenol, degradation of other organic compounds or chlorination of water may result in the chemical production of the compound.

Pentachlorophenol is moderately persistent in the **aquatic environment.** It was detected in lake water and fish six months after an accidental spill. The current use patterns of pentachlorophenol, primarily as a wood preservative, should preclude significant contamination of water as long as spills and industrial accidents are avoided.

Pentachlorophenol is moderately persistent in the **soil.** Published data report that persistence ranges from 21 days to five years. Under most conditions, pentachlorophenol will seldom persist in the soil for periods exceeding nine months and its half-life will frequently be far less than this. Numerous studies have identified soil microorganisms capable of degrading pentachlorophenol, but the extent of their distribution is unknown. Since the major use of pentachlorophenol does not involve application to the soil, the likeliest source of soil contamination is the leaching or bleeding of the preservative from treated wood. Such phenomena may result in low levels of pentachlorophenol contamination in the immediate vicinity (within several inches) of the treated wood.

Available data indicate that pentachlorophenol is not readily translocated by plants and that the compound is rapidly eliminated by mammals following exposure. Significant accumulation in plants and mammals is not likely to occur.

1/   Adapted from: The Biologic and Economic Assessment of <u>Pentachlorophenol, Inorganic Arsenicals, Creosote.</u> Volume 1: Wood Preservatives. 1980. USDA. Cooperative Impact Assessment Report. Technical Bulletin 1658-1, 435 pp.

Arsenicals

No problems have been found in the literature as to the effects of arsenical wood preservatives on the **environment.** Arsenate, the form present in aerobic soils, is bound tightly to the soil components and becomes unavailable for plant uptake or leaching.

Creosote

There are no recorded reports of wild or domestic animals being injured by creosote.

The amount of creosote as a liquid that enters the environment is relatively small. The fate of creosote in the environment is not known, but most components are quickly biodegraded.

CLASSIFICATION OF HERBICIDES
By CHEMICAL FAMILIES AND MODE OF ACTION

Chemical Family	Common Name	Trade Name	Mode of Action*
acetanilidies	alachlor	Lasso	GI
	bensulide	Betasan, Prefar	
	diphenamid	Dymid, Enide	
	pronamide	Kerb	
	propachlor	Ramrod	
	prynachlor	Basamaize	
alphatic carboxylic acids	dalapon	Dowpan, Basfapon	MI
	TCA	various	
benzoic acids	chloramben	Amiben	GR
	dicamba	Banvel	
	2,3,6-TBA	Trysben, Benzac	
benzonitriles	dichlobenil	Casoron	PI
	bromoxynil	Brominil, Buctril	
bipyridiliums	diquat	Ortho Diquat	C
	paraquat	Ortho Paraquat	
carbanilates	chloropropham	Chloro-IPC, Furloe	GI
	barban	Carbyne	
	phenmedipham	Betanal	
dinitroanilines	benefin	Balan	MP
	dinitramine	Cobex	
	fluchloralin	Basalin	
	nitralin	Planavin	
	profluralin	Tolban	
	trifluralin	Treflan	
diphenyl ethers	bifenox	Modown	C
inorganic compounds	AMS	Ammate	C
	boron	Borax, Borascue	
	copper sulfate	Bluestone, Cutrine	
	sodium chlorate	Atlacide, others	
organic arsenicals	DSMA	various	UC
	MAA	various	
	MSMA	various	
phenols	dinoseb	Premerge, Sinox	C

Chemical Family	Common Name	Tade Name	Mode of Action
phenoxy compounds acetic	2,4-D	various	GR
	MCPA	Methoxone, Weedar, Weedone	
	2,4,5-T	various	
butyric	2,4-DB	Butoxone, Butyrac	
	MCPB	Thistrol, Can-Trol	
propionic	2(2,4-DP)	Weedone	
	2(MCPP)	several	
	silvex (2,4,5-TP)	Kuron	
phthalic acids	DCPA	Dacthal	MI
	endothall	Aquathol, Hydrathol	
	naptalam	Alanap	
pyridines	picloram	Tordon	GR
pyridazinones	pyrazon	Pyramin	PI
substituted amino acids	glyphosate	Roundup	MI
		Rodeo	
sulfonyl ureas	chlorsulfuron	Glean, Telar	MI
	metasulfuron methyl	Ally, Escort	
thiocarbamates	butylate	Sutan	GI
	CDEC	Vegedex	
	cycloate	Ro-Neet	
	diallate	Avadex	
	EPTC	Eptam	
	EPTC + antidote	Eradicane	
	pebulate	Tillam	
	triallate	Fargo	
	vernolate	Vernam	
s-triazines (symmetrical)	ametryn	Evik	PI
	atrazine	AAtrex	
	cyanazine	Bladex	
	cyprazine	Outfox	
	prometon	Pramitol	
	simazine	Princep	
	terbutryn	Igran	
as-triazines (asymmetrical)	metribuzin	Sencor, Lexone	PI
triazoles	amitrole	Weedazol, Amino-triazole	CI
	methazole	Probe	

Chemical Family	Common Name	Trade Name	Mode of Action
uracils	bromacil	Hyvar	PI
	terbacil	Sinbar	
ureas	chloroxuron	Tenoran, Norex	PI
	diuron	Karmex	
	fenuron	Dybar	
	linuron	Lorox	
	monuron	Telvar	
	siduron	Tupersan	

*Mode of Action

MI	=	Metabolic Inhibitors
GR	=	Growth Regulators
PI	=	Photosynthetic Inhibitors
GI	=	Growth Inhibitors
MP	=	Mitotic Poisons
C	=	Contact Herbicides
UC	=	Unclear
CI	=	Chlorophyll Inhibitors

APPENDIX B

SELECTED BIBLIOGRAPHY

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Applied Weed Science, Merrill A. Ross and Carole A. Lembi

Flora of the Pacific Northwest, C. Leo Hitchcock and Arthur Cronquist.

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Herbicide Handbook, Weed Science Society of America.

Mode of Action of Herbicides, Floyd A. Aston and Alden S. Crafts.

A Guide to Selected Weeds of Oregon, Robert B. Hawkes, Tom D. Whitson and La Rea J. Dennis.

Controlling Pasture and Range Weeds in Montana, CES Bulletin 362, John R. Lacey and Celestine A. Lacey.

APPENDIX C

ORGANIZATION ADDRESSES

AWPA or American Wood Preservers' Association (6):
      P. O. Box 849, Stevensville, MD 21666.
      Tel. (301) 643-4161

AWPB or American Wood Preservers' Bureau (6):
      P. O. Box 6085, Arlington, VA 22206.
      Tel. (703) 931-8180

AWPI or American Wood Preservers' Institute (9):
      1945 Gallows Rd., Vienna, VA 22180

BOCA, "Basic Building Code." (6) by Building Officials and Code Administrators, International, Inc.
      17926 South Halstead,
      Homewood, IL 60430.
      Tel. (604) 799-2300

ICBO, "Uniform Building Code" (6) by International Conference of Building Officials,
      5360 South Workman Hill Road, Whittier, CA 90601.
      Tel. (213) 699-0541

SBCCI, "Standard Building Code" (6) by Southern Building Code Congress International, Inc.
      900 Montclair Road, Birmingham, AL 35213.
      Tel. (205) 591-1853